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STUDIES ON AUSTRALIAN MANGROVE ALGAE: II. COMPOSITION AND GEOGRAPHIC DISTRIBUTION OF COMMUNITIES IN SPENCER GULF, SOUTH AUSTRALIA

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Abstract: This study of algal communities associated with the temperate mangrove ecosystems of Spencer Gulf, South Australia documents the occurrence of 49 species including 10 Chlorophyta, 2 Cyanophyta, 9 Phaeophyta, and 28 Rhodophyta. Pertinent morphosystematic and distributional data are presented for each species. The Spencer Gulf mangrove algal flora is far more diverse than previously thought but is pedestrian and depauperate compared with the southern Australian marine algal flora as a whole. Most species are widespread on a global basis, although several typically tropical taxa also occur on Spencer Gulf mangroves and possible explanations for their occurrence are provided. Frequency data indicate that *Caloglossa leprieurii* occurs most commonly but that most species found occur only rarely or sporadically. Comparisons of the Spencer Gulf mangrove algal flora with those of mangrove ecosystems elsewhere in Australia suggest that the Spencer Gulf flora is comparatively species rich and shows distinct similarities to and differences from the mangrove algal flora in Victoria.

Data on Australian tropical and warm temperate mangrove algal communities are scant and pertain mainly to scattered floristic records (and one biomass production estimate) in Queensland and New South Wales (Cribb 1979, King 1981a, 1981b, 1981c, Saenger *et al.* 1977). Along the cool temperate southern Australian coast, mangrove ecosystems occur as geographically disjunct stands within Victoria, South Australia, and Western Australia (Fig. 1), but the only detailed account (Davey & Woelkerling 1980) of associated mangrove algae deals with community composition and geographic distribution in Victoria. Data for Western Australia are lacking entirely.

Within South Australian mangrove ecosystems, *Cladophora* sp., *Enteromorpha compressa* (Linnaeus) Greville, *Hormosira banksii* (Turner) Decaisne, *Ulva lactuca* Linnaeus and various diatoms have been regarded as common (Butler *et al.* 1977a, 1977b, Specht 1972, Womersley & Edmonds 1958, Wood 1937), whereas *Bostrychia* and *Caloglossa*, two of the most characteristic and cosmopolitan genera of mangrove algae (Post 1963), have been reported as apparently absent (Womersley & Thomas 1976, Womersley 1981a). Based on these isolated records, mangrove algal communities in South Australia would appear to differ markedly from those in Victoria where species of *Bostrychia* and *Caloglossa* are the most frequently occurring algae, species of *Enteromorpha* and *Ulva* tend to occur only sporadically, *Cladophora* occurs only rarely and *Hormosira* appears to be absent (Davey & Woelkerling 1980). The dearth of detailed data from South Australia has precluded a more thorough comparative assessment of these apparent differences.

Among those regions in South Australia where mangrove ecosystems occur (Fig. 1), Spencer Gulf has been regarded as noteworthy (Womersley 1981b) in the sense that at least three typically tropical benthic algae (*Acetabularia calyculus* Quoy et Gaimard, *Hormophysa triquetra* (Lamouroux) Kuetzing, *Sargassum decurrens* J. Agardh) are present, presumably because summer water temperatures are high enough for a sufficient period to allow survival (Womersley 1981c). Whether Spencer Gulf mangrove ecosystems also harbour typically tropical macroscopic algae has remained unknown as has the extent to which the algal communities in Spencer Gulf mangroves contrast with those in more tropical regions of Australia.

This account presents results of detailed studies on the floristic composition, frequency of species occurrence and geographic distribution of mangrove algal communities of Spencer Gulf, South Australia. It also examines the extent to which Spencer Gulf mangrove algal communities differ from those in Victoria and those in more tropical regions of Australia, and it includes comparisons of mangrove and open coast algal communities in terms of composition, diversity, and occurrences of endemic taxa.

Study Sites

The 10 mangrove algal communities (Fig. 2) selected for detailed study included the southern-most stands on both the eastern (Wallaroo) and western (Tumby Bay) shores, three stands in the far north (Blanche Harbour, Port Augusta, Red Cliff), two stands along tidal creeks (Arno Bay, Port Davis) and three other larger stands (Cowleds Landing, Franklin Harbour, Port Broughton).

In the two tidal creeks, pneumatophores occurred in permanently submerged areas only at Arno Bay (Fig. 4). Spencer Gulf mangrove ecosystems, like others in southern Australia (Macnae 1966), are based primarily in the mid to upper eulittoral zone, are dominated solely by *Avicennia marina* (Forster) Vierhapper, and usually are associated with a salt-marsh in the littoral-fringe (Butler *et al.* 1977a, 1977b). Data relating to tree height and stand size at the study sites are

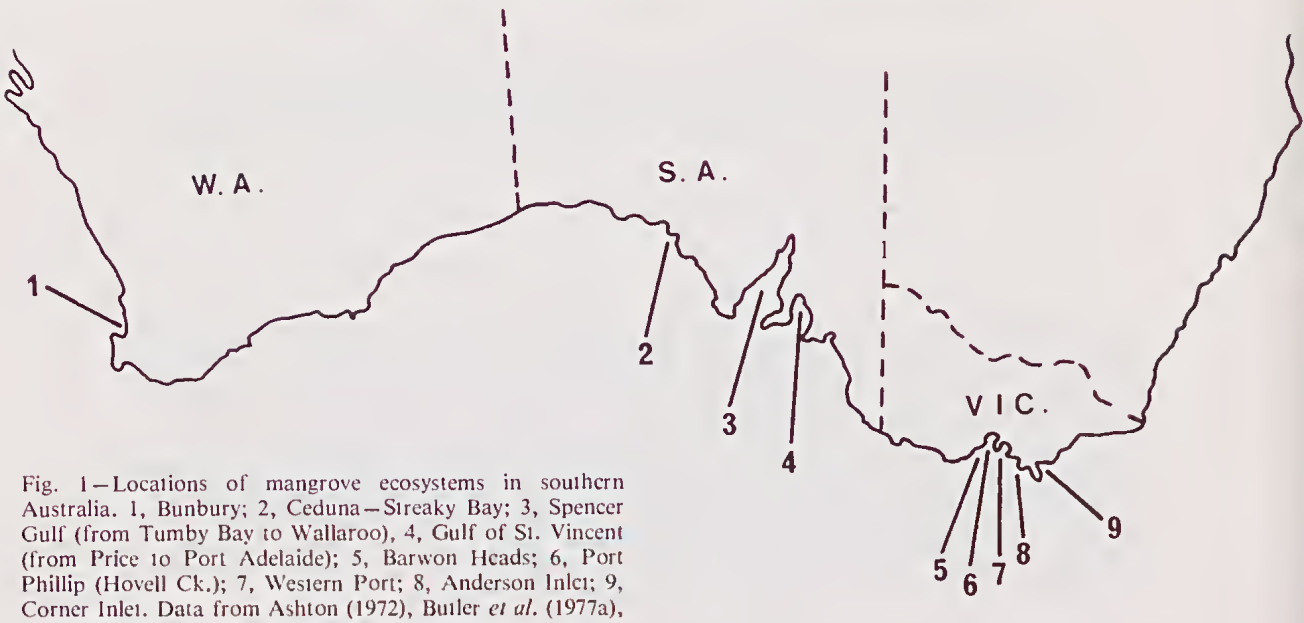

Fig. 1—Locations of mangrove ecosystems in southern Australia. 1, Bunbury; 2, Ceduna—Streaky Bay; 3, Spencer Gulf (from Tumby Bay to Wallaroo), 4, Gulf of St. Vincent (from Price to Port Adelaide); 5, Barwon Heads; 6, Port Phillip (Hovell Ck.); 7, Western Port; 8, Anderson Inlet; 9, Corner Inlet. Data from Ashton (1972), Butler *et al.* (1977a), Macnae (1966) and Saenger *et al.* (1977).

summarized in Table 1. Abundant pneumatophores (Figs 3, 4) beneath and beyond the edge of the *Avicennia* canopy are the main substrate for macroscopic algae.

Study site selection also took account of certain physical parameters which divide Spencer Gulf into two distinct regions. The tides have a phase difference between the far north (i.e. north of Port Davis) and the rest of the Gulf and change with greater amplitude in the north (Easton 1974). As a result, mean lowest tides during summer months tend to occur during the daytime in the south and at night in the north (Australian National Tide Tables 1981). Thus the mangrove algal communities south of Port Davis are emergent longer during periods of extreme salinities, air temperatures, and desiccating conditions that commonly occur at neap tide in summer.

Water circulation in Spencer Gulf inhibits exchange between the northern (i.e. north of Franklin Harbour) and southern parts, and Tronson (1974) estimates that at least two years are required for a total exchange to occur. A salinity gradient ranging from 36 g/kg in the far south to 45 g/kg in the far north also occurs (Bullock 1975, Womersley 1981a: 217). While mean monthly surface water temperatures along the central South Australian open coast range from 14-19°C, the range part way up Spencer Gulf is about 12-25°C and at the head it is 13-28°C (Womersley 1981a: 216). Thus summer surface water temperatures in the central and northern parts of the gulf are 6-9°C warmer than those of the adjacent open coast. The extent to which these physical factors affect mangrove algal community composition and species distribution within the Gulf has not been examined previously, and sites for the present study were chosen partly to obtain data relevant to such an examination.

TABLE 1
MEASUREMENTS OF *Avicennia* HEIGHT AND FRINGE WIDTH, AND APPROXIMATIONS OF FRINGE LENGTH, AT TEN MANGROVE COMMUNITIES IN SPENCER GULF, SOUTH AUSTRALIA

Locality	Height m	Approximate Fringe Length km	Maximum Fringe Width m
Arno Bay	5.0	2	25
Blanche Harbour	3.5	5	110
Cowleds Landing	4.0	30	100
Franklin Harbour	4.5	18	75
Port Augusta	3.0	2	200
Port Broughton	6.0	4	80
Port Davis	4.0	4	50
Red Cliff	5.0	5	320
Tumby Bay	1.5	3	75
Wallaroo	3.0	2	90

MATERIALS AND METHODS

Two procedures were employed to obtain entire *Avicennia* pneumatophores for algal community composition and frequency data from each study site during the period March to July 1981. One involved using a restricted random sampling regime (Goldsmith & Harrison 1976) to collect 50 pneumatophores from each of three 10 m wide, 50 m long belt transects. Each belt transect was bisected lengthwise into two laterally contiguous 5 m wide strips contoured so that one strip was situated just within the shaded margin of the *Avicennia* canopy while the other strip lay in the adjacent sun-exposed seaward fringe of pneumatophores beyond the

canopy (Fig. 3). In the tidal creek at Arno Bay, however, one strip of each transect was situated along the creek bank at low tide while the adjacent strip lay within the permanent creek water. From each transect, 25 pairs of random co-ordinate pneumatophores were collected; one of each pair came from the strip under the shaded canopy (or in the creek) while the other came from the strip in the sun-exposed region (or along the creek bank).

The second collecting procedure involved gathering additional pneumatophores from throughout the mangrove fringe if they appeared to harbour algal species not obtained during the transect sampling. This was the only procedure used at Port Broughton, where pneumatophores bearing algae occurred so intermittently that transect sampling was not undertaken.

All pneumatophores were preserved in 1:10 commercial formalin-seawater solution and returned to the laboratory for analyses. Algal community composition data were compiled from assays of all pneumatophores collected at each locality. These data did not take account of any diatoms (Bacillariophyta) present and included only those species of blue green algae (Cyanophyta) which formed macroscopic colonies. Permanent slides, liquid preserved material, and/or dried voucher specimens have been deposited in the La Trobe University Botany Department Herbarium (LTB—see Holmgren & Keuken 1977).

Species frequency data for each locality except Port Broughton were calculated from results of a species presence/absence survey of the 150 pneumatophores collected in the three transects by using the formula:

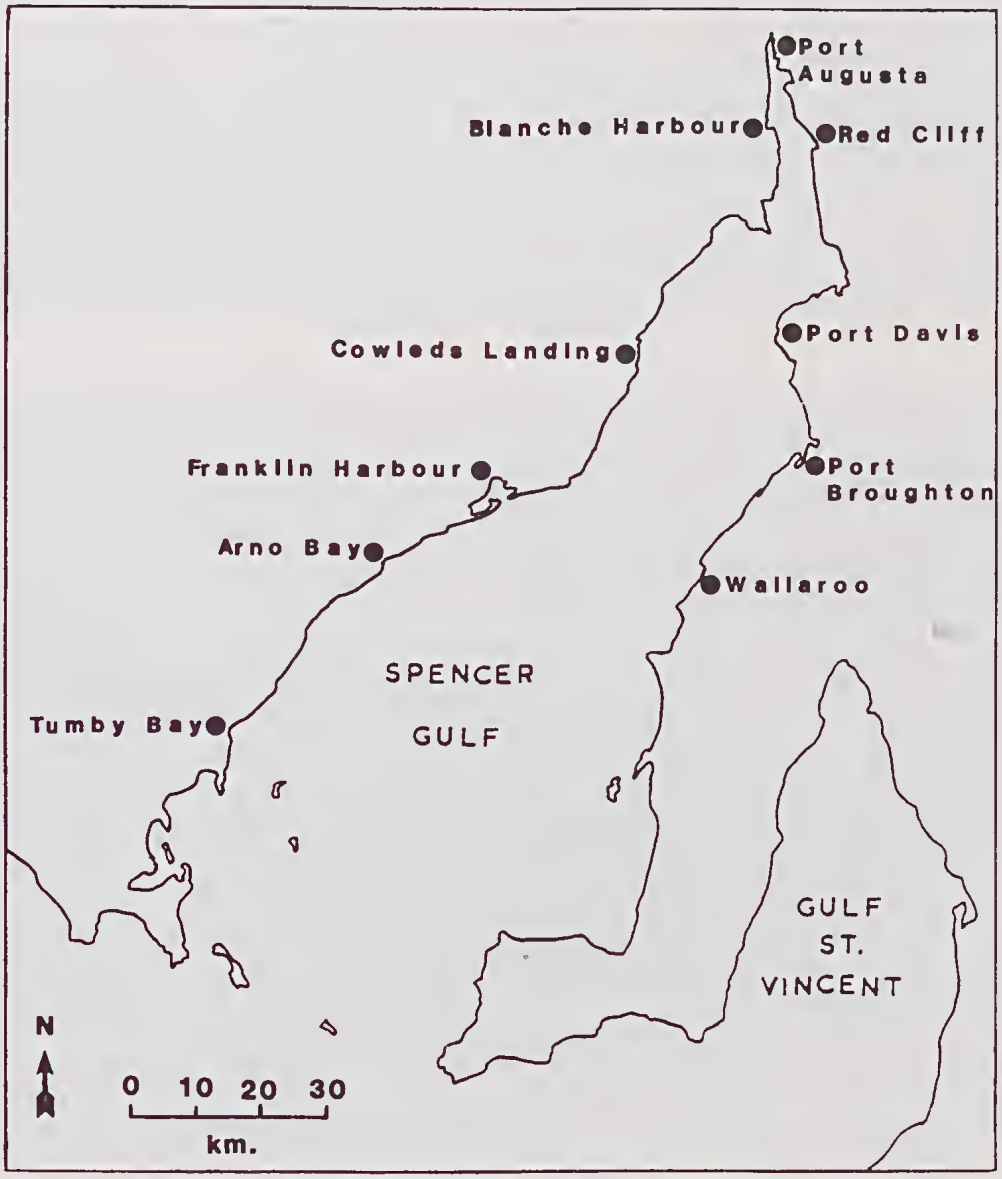

Fig. 2—Location of study sites in Spencer Gulf, S.A.

$F = \Sigma N/N$, where
F = the absolute frequency;
ΣN = the number of pneumatophores on which a particular alga occurred;
N = the total number of pneumatophores surveyed.

Following Davey & Woelkerling (1980), the relative profusion of taxa has been determined from absolute frequency data, and species have been assigned to one of five categories: *Rare* ($F < 0.05$); *Sporadic* ($F = 0.05$ to 0.24); *Occasional* ($F = 0.25$ to 0.49); *Common* ($F = 0.50$ to 0.75); *Abundant* ($F > 0.75$). In the text, the word 'prevalent' is used to include both common and abundant frequency classes.

COMMUNITY COMPOSITION AND SPECIES DISTRIBUTION

Forty-nine species of algae, including 10 Chlorophyta, 2 Cyanophyta, 9 Phaeophyta and 28 Rhodophyta, were recorded. At any particular locality 5-26 species were detected (Table 2), and with the exceptions of Port Augusta, Port Broughton and Port Davis, red algae predominated. Taxa from all four algal Divisions were encountered in 7 of the 10 mangrove stands; macroscopic colonies of blue green algae were not detected at Arno Bay, Port Broughton or Port Davis and brown algae were not observed at Port Broughton or Port Davis. Sixteen species were found at 5 or more localities while 15 other species were recorded from only one locality each. Relationships between distribution and frequency data are considered later.

Table 2
Summary of the Mangrove Algal Community Composition at Spencer Gulf Study Sites

Locality	CHLOROPHYTA	CYANOPHYTA	PHAEOPHYTA	RHODOPHYTA	TOTAL
Arno Bay	8	–	3	13	24
Blanche Harbour	5	2	1	5	13
Cowleds Landing	5	2	4	15	26
Franklin Harbour	8	2	4	9	23
Port Augusta	5	1	4	3	13
Port Broughton	3	–	–	2	5
Port Davis	4	–	–	3	7
Red Cliff	4	2	3	12	21
Tumby Bay	7	1	1	7	16
Wallaroo	7	1	1	16	25

COMMUNITY COMPOSITION LIST

Details of locality occurrences of species in the following list may be obtained from Table 4, which also summarizes frequency data.

Fig. 3 – Portion of the mangrove ecosystem at Cowleds Landing showing sun exposed and canopy shaded regions along the seaward margin at low tide.

Fig. 4—Portion of the mangrove ecosystem at Arno Bay showing the eulittoral (E) and sublittoral (S) creek environment at low tide. Note emergent pneumatophores in foreground; permanently submerged pneumatophores (not visible) also occur within the creek, which is up to 1 m deep at low tide.

Division Chlorophyta
Order Ulvales
Family Ulvaceae
Genus **Enteromorpha** Link 1820

Enteromorpha sp.

Specimens Examined: LTB 12190, 12233, 12243, 12259, 12281, 12292, 12316, 12327, 12348, 12359.

Remarks: *Enteromopha* plants occurred on pneumatophores at all sites except Red Cliff and also grew loose on the sun-exposed mud flat at Tumby Bay. Most plants were less than 2 cm tall and none could be identified to species with confidence.

Genus **Percursaria** Bory 1828

P. percursa (C. Agardh) Rosevinge 1893: 963. Abbott & Hollenberg 1976: 70, fig. 23. Bliding 1963: 20, figs 5, 6.

Type Locality: Denmark.

Reported Distribution: Widespread.

Specimens Examined: LTB 12172, 12197, 12223, 12251, 12279, 12300, 12320.

Remarks: *P. percursa* occurred attached to pneumatophores under the *A. marina* canopy and in the sun-explosed seaward margin, and was encountered as an epiphyte on *Cystophyllum onustum* at Red Cliff. The only previous record of this taxon in southern Australia was on mangroves at Hovell's Creek, Victoria (Davey & Woelkerling 1980).

Genus **Ulva** Linnaeus 1753

U. lactuca (Linnaeus) C. Agardh, 1821: 409. Bliding 1968: 540, figs 3-5. Womersley 1956: 353.

Type Locality: Sweden.

Reported Distribution: Widespread.

Specimens Examined: LTB 12167, 12231, 12244, 12262, 12311.

Remarks: Plants up to 20 cm tall occurred on sun-exposed pneumatophores at Arno Bay and Wallaroo. Smaller specimens, up to 3 cm tall, were encountered at Port Davis, Port Augusta and Franklin Harbour. *U. lactuca* has been found on *Avicennia* pneumatophores in Queensland (Cribb 1979, Saenger *et al.* 1977) and Victoria (Davey & Woelkerling 1980).

Order Cladophorales
Family Cladophoraceae
Genus **Chaetomorpha** Kuetzing 1845

C. aerea (Dillwyn) Kuetzing 1849: 379. Womersley 1956: 355.

Type Locality: Cromer, Britain.

Reported Distribution: Widespread.

Specimens Examined: LTB 12181, 12360.

Remarks: Filaments 10-20 cells long, 250-350 μm broad and attached by a subelavate, lobed, basal cell occurred on pneumatophores at Arno Bay and Wallaroo.

C. capillaris (Kuetzing) Boergesen 1925: 45, fig. 13.

Feldmann 1937: 207, fig. 17. Womersley 1956: 356.
Type Locality: Nice, France.
Reported Distribution: Mediterranean and Atlantic Ocean. In Australia from Kangaroo Island, Spencer Gulf and Western Port.
Specimens Examined: LTB 12293.
Remarks: Entangled mats of *C. capillaris* occurred in patches on pneumatophores. Davey & Woelkerling (1980) found this species on mangroves throughout Western Port.

Genus **Cladophora** Kuetzing 1843

Cladophora sp.
Specimens Examined: LTB 12176, 12189, 12214, 12246, 12260, 12278, 12301, 12312, 12344, 12356, 12361.
Remarks: Plants of *Cladophora* were found attached to pneumatophores at all localities except Port Davis, and at Red Cliff and Cowleds Landing plants also grew on *Cystophyllum onustum*. Cells were mostly 40-70 μm broad and 150-230 μm long, but specimens were too small (<2 cm tall) or too young to identify to species reliably.

Genus **Cladophorella** Fritsch 1944

C. marina Chapman 1956: 442, fig. 92b, c.
Type Locality: Orongo Bay, New Zealand.
Reported Distribution: From Orongo Bay and Uruiti Bay, New Zealand; South Australia.
Specimens Examined: LTB 12178, 12210, 12261, 12275, 12295, 12313, 12343.
Remarks: The Spencer Gulf collections have been referred to *Cladophorella marina* because their morphology agreed more closely with that species than with other species assigned to the genus (Table 3). Chapman (1956) did not supply data on wall diameter or cell dimensions, but the latter have been calculated from his figure 92b. Plants commonly formed dense veneer-like mats on lower portions of pneumatophores both in the sun exposed and shaded regions of the communities. Womersley (1956, 1971) did not record this species from southern Australia but Cribb (1965, 1979) recorded the related *C. calcicola* from Queensland. The relationships of *Cladophorella* Fritsch 1944 to the genus *Wittrockiella* Wille 1909 require clarification and are under current review (Van den Hoek, H.B.S. Womersley, pers. comm.).

Genus **Rhizoclonium** Kuetzing 1843

R. implexum (Dillwyn) Kuetzing 1845: 206. Abbott & Hollenberg 1976: 92, fig 45. Newton 1931: 93. Rueness 1977: 243.
Type Locality: Ireland.
Reported Distribution: Widespread.
Specimens Examined: LTB 12185, 12234, 12252, 12294, 12310.
Remarks: Plants occurred on *Avicennia* pneumatophores at Arno Bay, Franklin Harbour, Port Davis and Tumby Bay and also occurred entangled with *Bostrychia* and *Percursaria* at Wallaroo. Most filaments were 17-22 μm broad, unbranched, and composed of cells 2-6(-9) diameters long, each containing a reticulate chloroplast mostly with 5-8 pyrenoids. The Spencer Gulf plants agreed with the concept of *R. implexum* presented by Abbott & Hollenberg (1976) and Rueness (1977). This species apparently has not been recorded previously from southern Australia (Womersley 1956, p. 361, 362).
R. riparium (Roth) Harvey 1849: pl. 239. Abbott & Hollenberg 1976: 92, fig. 46, pl. 1, fig. 9. Rueness 1977: 243. Womersley 1956: 361.
Type Locality: Northern Europe.
Reported Distribution: Widespread.
Specimens Examined: LTB 12182, 12196, 12212, 12228, 12241, 12270, 12282, 12308, 12338.
Remarks: *Rhizoclonium riparium* occurred on pneumatophores amongst other algae at all sites except Blanche Harbour and Port Broughton and was abundant at Arno Bay and Port Davis. Most filaments were 20-50 μm broad, rarely possessed rhizoidal branches, and were composed of cells 1-2.5 (-4) diameters long; each contained a reticulate chloroplast with 10 or more pyrenoids. The Spencer Gulf plants agreed most closely with the concept of *R. riparium* presented by Rueness (1977). Californian plants (Abbott & Hollenberg 1976) appear to be more robust and possess more rhizoidal branches. Davey & Woelkerling (1980) reported this species from four mangrove communities in Victoria.

Order Chaetophorales
Family Chaetophoraceae
Genus **Sporocladopsis** Nasr 1947

S. novaezelandiae Chapman 1949: 496, fig. 4; 1956: 433, fig. 85a-c.
Type Locality: Bay of Islands, New Zealand.
Reported Distribution: North Island of New Zealand; Queensland, southern Australia.
Specimens Examined: LTB 12288, 12319, 12336.
Remarks: Sterile plants occurred on pheumatophores as inconspicuous epiphytes. This species was not recorded from southern Australia by Womersley (1956, 1971).

Division Cyanophyta
Order Oscillatoriales
Family Rivulariaceae
Genus **Rivularia** Roth 1797

R. atra Roth 1806: 340. Drouet 1973: 164; 1978: 237. Umezaki 1961: 105, pl.21, fig. 2a-c. Womersley 1946: 132.
Type Locality: West Germany.
Reported Distribution: Widespread.
Specimens Examined: LTB 12187, 12202, 12269, 12276, 12296, 12314, 12333.
Remarks: *R. atra* formed solid colonies, up to 1 cm diameter on pneumatophores in the sun-exposed and shaded regions of the communities. Trichomes were 3-12 μm in diameter, sheathed in a thick hyaline coat, usually bore heterocysts of 10-12μm diameter, and tapered to a thin hair. Drouet (1973) placed this species in synonomy with *Calothrix crustacea* Schousboe & Thuret.

R. polyotis (J. Agardh) Bornet & Flahault 1886: 360. Umezaki 1961: 103. Womersley 1946: 134.
Type Locality: Mediterranean coast of France.
Reported Distribution: Widespread.
Specimens Examined: LTB 12203, 12277, 12315, 12334.
Remarks: *R. polyotis* occurred on pneumatophores; trichomes, 2-8 μm in diameter, were sheathed in a thick hyaline coat, bore basal heterocysts 6-10 μm in diameter, and usually tapered to a thin hair. Plants formed soft, hollow colonies up to 2 cm in diameter.

Division Phaeophyta
Order Ectocarpales
Family Ectocarpaceae
Genus **Ectocarpus** Lyngbye 1819

E. siliculosus (Dillwyn) Lyngbye 1819: 131. Russell 1966: 275 *et seq.*, figs. 3, 4. Womersley 1967: 190.
Type Locality: Europe.
Reported Distribution: Widespread in temperate and boreal seas.
Specimen Examined: LTB 12253.
Remarks: *E. siliculosus* occurred sporadically on continually submerged pneumatophores, grew up to 2 cm tall, and bore plurilocular sporangia. *E. siliculosus* also has been recorded from Victorian mangrove communities (Davey & Woelkerling 1980).
Ectocarpus sp.
Specimen Examined: LTB 12267.
Remarks: Two small plants with plurilocular sporangia were found in the sun-exposed seaward margin at Port Augusta. Cells were 16-20 μm broad, 20-35 μm long and plurilocular sporangia, borne terminally, were 50-80 μm long and 25-30μm broad. The plants were insufficiently developed for reliable species identification.

Genus **Gilfordia** (Batters) Hamel 1939

G. sordida (Harvey) Clayton 1974: 785, fig. 12G1, G2, 15A-F, 26A-K.
Type Locality: Georgetown, Tasmania.
Reported Distribution: Southern Australia, Queensland.
Specimen Examined: LTB 12362.
Remarks: *G. sordida* was abundant at Wallaroo in June, occurring attached to pneumatophores and/or intermixed with other algae in all regions of the community. Plants up to 15 cm tall, with filaments 20-50 μm in diameter were collected. Unilocular sporangia occurred rarely.

Genus **Kuetzingiella** Kuckuck 1956

Kuetzingiella sp.
Specimens Examined: LTB 12245, 12266, 12280, 12289, 12317, 12337.
Remarks: Filaments consisted of 20-30 cells approximately 10 μm broad and 5 μm long. Plurilocular sporangia 100-200 μm long and 18-22 μm broad usually were present. According to Clayton (1974), the taxonomy of southern Australian *Kuetzingiella* species is uncertain and in need of revision.

Order Sphacelariales
Family Sphacelariaceae
Genus **Sphacelaria** Lyngbye 1819

S. furcigera Kuetzing 1855: 27, pl.90. Womersley 1967: 199.
Type Locality: Karak Is., Persian Gulf.
Reported Distribution: Widespread.
Specimens Examined: LTB 12200, 12254, 12263, 12303.
Remarks: Plants up to 1 cm tall were found on pneumatophores at Red Cliff, Port Augusta, Franklin Harbour and Arno Bay. They also grew as epiphytes on *Cystophyllum onustum* at Red Cliff and Cowleds Landing. Some plants bore plurilocular or unilocular sporangia and most produced long-armed, biradiate propagules.
S. tribuloides (Meneghini) De Toni 1895: 502. Taylor 1960: 211, pl.29 fig 6. Womersley 1967: 201.
Type Locality: Italy.
Reported Distribution: Widespread in tropical and temperate seas.
Specimens Examined: LTB 12201, 12264, 12304.
Remarks: Several plants up to 1 cm tall were found on pneumatophores at Port Augusta, Red Cliff and Franklin Harbour. Those at Red Cliff were intermixed with *S. furcigera*. Short-armed, triradiate propagules occurred on most plants.

Order Dictyotales
Family Dictyotaceae
Genus **Dictyota** Lamouroux 1809

Dictyota sp.
Specimens Examined: LTB 12214, 12351, 12363.
Remarks: Sterile plants, up to 3 cm tall, were epiphytic on *Cystophyllum onustum* at Red Cliff and Cowleds Landing, and were attached to pneumatophores in the sun-exposed seaward margin at Wallaroo in June. Plants were insufficiently developed for reliable species identification.

Order Fucales
Family Cystoseiraceae
Genus **Cystophyllum** J. Agardh 1848.

C. onustum (Mertens) J. Agardh 1848: 230. Womersley 1967: 254.
Type Locality: Western Australia.
Reported Distribution: All around Australia; Indian Ocean.
Specimens Examined: LTB 12214, 12349.
Remarks: A large, solitary plant was attached to the base of a mangrove tree at Red Cliff; a second plant was found attached to shells under the canopy at Cowleds Landing. Both plants harboured a number of epiphytes.

Family Hormosiraceae
Genus **Hormosira** (Endlicher) Meneghini 1838

H. banksii (Turner) Decaisne 1842: 331. Clarke & Womersley 1981: 497 *eq seq.* King 1981a: 325, figs 9, 12; 1981b: 107; 1981c: 569 *et seq.* Womersley 1967: 249-250.
Type Locality: 'Novae Hollandiae'.

Reported Distribution: From King George Sound, Western Australia, around southern Australia; New South Wales; Lord Howe Island; Norfolk Island; New Zealand.
Specimens Examined: LTB 12166, 12199, 12224, 12225, 12326, 12329, 12347.
Remarks: Plants up to 25 cm tall with swollen vesicles, were attached to the lower half of pneumatophores and loose lying on mud surfaces at Wallaroo, Red Cliff, Franklin Harbour, and Cowleds Landing. The loose lying form was also encountered at Tumby Bay. King (1981a, 1981b, 1981c) provided data on an extensive loose lying community of *H. banksii* within the mangroves of southern Botany Bay in New South Wales; he estimated that mean dry weight biomass ranged from 280 g m^{-2} in late winter (August) to 638 g m^{-2} in mid-summer and suggested an annual biomass production rate of approximatley 400 g m^{-2}. Clark & Womersley (1981, p. 500) reported an unattached population of plants occurring among mangroves at Port Arthur, South Australia at the north end of St. Vincent Gulf. Individuals up to 50 cm long were encountered.

Division Rhodophyta
Order Bangiales
Family Erythropeltidaceae
Genus **Asterocytis** (Hansgirg) Schmitz 1896.

A. ornata (C. Agardh) Hamel 1925: 40.
A. ramosa (Thwaites) Schmitz 1896: 314. Abbott & Hollenberg 1976: 283. Taylor 1960: 287.
Type Locality: British Isles.
Recorded Distribution: Widespread in temperate seas.
Specimens Examined: LTB 12211, 12257, 12302, 12340, 12358, 12364.
Remarks: *A. ornata* was attached to pneumatophores in the sun-exposed seaward margin at Port Broughton and Cowleds Landing and occurred at Wallaroo in June but not in March. Plants were also encountered as epiphytes on *Chondria* sp. at Arno Bay and Wallaroo, on *Polysiphonia teges* and *Sphacelaria furcigera* at Red Cliff, and on *Cystophyllum onustum* at Cowleds Landing.

Genus **Erythrotrichia** Areschoug 1850

E. carnia (Dillwyn) J. Agardh 1883: 15. Abbott & Hollenberg 1976: 286, fig. 228. Newton 1931: 242. Taylor 1960: 291.
Type Locality: Wales, Gt. Britain.
Reported Distribution: Widespread.
Specimen Examined: LTB 12247.
Remarks: *E. carnea* grew on pneumatophores, on *Ulva lactuca* and on *Chondria* sp.

Order Nemalionales
Family Acrochaetiaceae
Genus **Audouinella** Bory 1823

A. botryocarpa (Harvey) Woelkerling 1971: 37. Searles & Schneider 1978: 100.
Type Locality: King George Sound, W. Australia.
Reported Distribution: Bunbury, Western Australia to Point Lonsdale, Victoria, and Tasmania; New Zealand; North Carolina.
Specimen Examined: LTB 12248.
Remarks: Plants were attached both to continually submerged and mud-flat pneumatophores at Arno Bay, and usually bore monospores. Woelkerling (1970) provided a detailed account of this alga.
A. daviesii (Dillwyn) Woelkerling 1971: 28, figs 7A-J, 22A-B; 1973: 550, fig. 32-43.
Type Locality: Bantry Bay, Ireland.
Reported Distribution: Widespread.
Specimens Examined: LTB 12249, 12365.
Remarks: Plants of *A. daviesii* grew attached to continually submerged and mud-flat pneumatophores and also on *Ulva lactuca* at Arno Bay. Plants were encountered at Wallaroo in June but not in March.
A. savianna (Meneghini) Woelkerling 1973: 560-565, figs 56-60.
Type Locality: Genoa, Italy.
Reported Distribution: Widespread.
Specimen Examined: LTB 12250.
Remarks: Monosporangial plants were found attached to continually submerged and mud-flat pneumatophores at Arno Bay. A detailed account of this taxon in southern Australia was provided by Woelkerling (1971) using the name *A. thuretii* (Bornet) Woelk. Subsequent comparisons of the type collections of *A. savianna* and *A. thuretii* (Woelkerling 1973) indicated that the two taxa were conspecific, with *A. savianna* having priority.

Order Gelidiales
Family Gelidiaceae
Genus **Gelidiella** Feldmann & Hamel 1934

G. nigrescens (Feldmann) Feldmann & Hamel 1934: 533. Feldmann & Hamel 1937: 222, fig. 7.
Type Locality: Algeria.
Reported Distribution: Uncertain.
Specimens Examined: LTB 12175, 12323.
Remarks: Dense stands of tetrasporangial plants colonized the lower half of pneumatophores at Wallaroo. Plants were more common under the canopy than in sun-exposed regions. A single plant also was collected at Franklin Harbour. The two species of *Gelidiella* recorded in this study closely fit the reproductive and morphological descriptions in Feldmann and Hamel (1934, 1937), and apparently have not been recorded previously from southern Australia.
G. tenuissima Feldmann & Hamel 1937: 226, figs 11, 12A-E.
= *G. panosa* (Bornet) Feldmann & Hamel 1934: 534.
Type Locality: Biarritz, France.
Reported Distribution: Uncertain.
Specimens Examined: LTB 12173, 12207, 12238, 12335, 12366.
Remarks: *G. tenuissima* was common under the *Avicennia* canopy at Wallaroo and Arno Bay and occurred infrequently at Cowleds Landing, Port Augusta and Red

Cliff. Plants were usually fertile and bore either cystocarps or tetrasporangia.

Genus **Gelidium** Lamouroux 1813

G. pusillum (Stackhouse) Le Jolis 1863: 139. Chapman 1969: 89. Dixon & Irvine 1977: 129, fig. 48A-J. May 1965: 371.
Type Locality: England.
Reported Distribution: Widely distributed in tropical and temperate waters.
Specimen Examined: LTB 12367.
Remarks: Sterile plants occurred infrequently on pneumatophores under the *Avicennia* canopy.

Order Cryptonemiales
Family Corallinaceae

Remarks: With few exceptions, southern Australian representatives of this family are poorly known and never have been the subject of monographic studies. Moreover, speeies concepts among nongeniculate taxa generally are rather confused and many questions coneerning generic concepts also remain unanswered. Consequently the corallines found during the study have not been identified to species, and placement into genera is based on concepts presented by Johansen (1981).

Genus **Heteroderma** Foslie 1909

Heteroderma sp.
Specimens Examined: LTB 12368, 12369.
Remarks: *Heteroderma* sp. was common on pneumatophores at Wallaroo, and occurred infrequently at Cowleds Landing. Many plants possessed either female or tetrasporangial conceptacles.

Genus **Jania** Lamouroux 1812

Jania sp.
Specimen Examined: LTB 12372.
remarks: One small sterile plant, 5 mm tall, was found at Wallaroo in July.

Genus **Lithothamnium** Philippi 1837

Lithothamnium sp.
Specimen Examined: LTB 12318.
Remarks: Specimens occurred on the lower portion of pneumatophores under the canopy at Franklin Harbour. Most plants bore either female or tetrasporangial eonceptacles. The concept of *Lithothamnium* as a genus is under review (Woelkerling 1981).

Genus **Neogoniolithon** Setchell & Mason 1943

Neogoniolithon sp.
Specimens Examined: LTB 12370, 12371.
Remarks: Crusts up to 4 mm thick occurred on pneumatophores in sun-exposed and shaded regions. Most plants had male or female or tetrasporangial conceptacles.

Genus **Phymatolithon** Foslie 1898

Phymatolithon sp.
Specimen Examined: LTB 12373.
Remarks: Tetrasporangial plants encrusted the lower portions of pneumatophores.

Order Ceramiales
Family Ceramiaceae
Genus **Centroceras** Kuetzing 1841

C. clavulatum (C. Agardh) Montagne 1846: 140. Abbott & Hollenberg 1976: 604, fig. 547. May 1965: 371. Taylor 1960: 537.
Type Locality: Caloa, Peru.
Reported Distribution: Widely distributed in tropical and temperate seas.
Specimens Examined: LTB 12188, 12209, 12217, 12256, 12286, 12321, 12357.
Remarks: Sterile plants up to 3 em tall were found entangled with other algae at Wallaroo, and attached to pneumatophores at Red Cliff, Franklin Harbour, Arno Bay and Tumby Bay. Plants were epiphytic on *Cystophyllum onustum* at Red Cliff and Cowleds Landing. No sun or shade preference was evident. Cribb (1979) recorded this species from Queensland mangroves.

Genus **Spyridia** Harvey 1833

S. filamentosa (Wulfen) Harvey 1833: 336. Womersley & Cartledge 1975: 222, fig. 1A-D.
Type Locality: Adriatic Sea.
Reported Distribution: Widespread in tropical and temperate seas.
Specimens Examined: LTB 12170, 12198, 12221, 12283, 12285, 12309, 12325, 12354.
Remarks: Plants usually grew on the lower half of pneumatophores in both the sun-exposed and shaded regions of the community. *S. filamentosa* was encountered growing on mud surfaces and attached to shells at Tumby Bay and Red Cliff, and as an epiphyte on *Cystophyllum onustum* at Red Cliff and Cowleds Landing. All specimens were sterile. This species occurs on mangroves in Queensland (Cribb 1979, Saenger *et al.* 1977).

Family Rhodomelaceae
Genus **Bostrychia** Montagne 1842

B. moritziana (Sonder in Keutzing) J. Agardh 1863: 862. Post 1963: 57; 1964: 244.
Type Locality: French Guiana.
Reported Distribution: Widespread in tropical and temperate seas.
Specimens Examined: LTB 12180, 12195, 12230, 12273, 12305, 12330.
Remarks: *B. moritziana* was locally abundant at Wallaroo, Port Davis, Red Cliff, Blanche Harbour, Cowleds Landing and Franklin Harbour. Plants were most common under the *Avicennia* canopy and often were intermixed with *B. radicans*. Tetrasporangial plants were rare, and cystocarpic or male plants were not found. Davey and Woelkerling (1980) found this to be the most widely distributed species of *Bostrychia* in Victorian mangrove ecosystems, and Cribb (1979) and Saenger *et al.* (1977) recorded the species from Queensland.

B. radicans (Montagne) Montagne 1850: 286.

Type Locality: Sinnamary, French Guiana.
Reported Distribution: Widely distributed in tropical and temperate seas.
Specimens Examined: LTB 12177, 12194, 12229, 12236, 12272, 12287, 12306, 12334.
Remarks: *B. radicans* was the most abundant and widespread species of *Bostrychia* in Spencer Gulf, occurring at all sites except Port Broughton and Port Augusta. Plants often formed mats on pneumatophores under the *Avicennia* canopy and in some cases bore spermatangia, cystocarps or tetrasporangia. The only previous record of this taxon in southern Australia was from the mangrove environment in Victoria (Davey & Woelkerling 1980); Saenger *et al.* (1977) and Cribb (1979) recorded this species from Queensland.

Genus **Caloglossa** J. Agardh 1876

C. leprieurii (Montagne) J. Agardh 1876: 499.
Type Locality: Cayenne, French Guiana.
Reported Distribution: Widespread in tropical and temperate seas.
Specimens Examined: LTB 12179, 12193, 12232, 12235, 12258, 12274, 12307, 12331.
Remarks: *C. leprieurii* was often in association with species of *Bostrychia* and sometimes forming dense, pure stands on pneumatophores in both sun-exposed and shaded regions. Tetrasporangial and cystocarpic plants were found on occasions. This species occurs commonly on mangrove pneumatophores elsewhere in Australia (see Cribb 1979, Davey & Woelkerling 1980).

Genus **Chondria** C. Agardh 1817

Chondria sp.
Specimens Examined: LTB, 12204, 12240, 12291, 12374.
Remarks: *Chondria* sp. occurred infrequently at Wallaroo, Tumby Bay and Red Cliff. Plants were attached to pneumatophores in the sun-exposed seaward margin, and were epiphytic on *Cystophyllum onustum* at Cowleds Landing and on *Ulva lactuca* at Arno Bay. Plants were insufficiently developed for reliable species identification.

Genus **Diplocladia** Kylin 1956

D. patersonis (Sonder) Kylin 1956: 504. May 1965: 383.
Type Locality: Cape Paterson, Victoria.
Reported Distribution: South Australia, Tasmania, Victoria.
Specimens Examined: LTB 12171, 12290, 12324.
Remarks: *D. patersonis* plants up to 10 cm tall were collected both in sun-exposed and shaded areas at Wallaroo, Franklin Harbour and Tumby Bay. The Wallaroo samples collected during winter (June) bore tetrasporangia. Davey & Woelkerling (1980) reported this species on mangroves at two localities in Victoria.

Genus **Herposiphonia** Nageli 1846

Herposiphonia sp.
Specimens Examined: LTB 12339, 12375.
Remarks: The two collections of *Herposiphonia* obtained during this study probably are referrable to different species but both were sterile, and as noted by Abbott & Hollenberg (1976: 720) such specimens often are difficult to identify to species level with confidence. Plants (sp. "A") in the Cowleds Landing collection (LTB 12339) had determinate branches 40-60 μm in diameter, which were 7-14 segments long and had 6-7 pericentral cells. These specimens appeared to be most similar to *H. delicatula* Hollenberg (1968: 540). Plants (sp. "B") in the Wallaroo collection (LTB 12375) had determinate branches 70-80 μm in diameter which were mostly 12-18 segments long and had 8-9 pericentral cells. These specimens appeared to be most similar to *H. tenella* f. *secunda* (C. Agardh) Hollenberg (1968).

Genus **Laurencia** Lamouroux 1813

Laurencia sp.
Specimens Examined: LTB 12168, 12208, 12216, 12355.
Remarks: Sterile plants up to 3 cm tall were found on pneumatophores at Wallaroo and Red Cliff, and other plants occurred epiphytically on *Cystophyllum onustum* at Red Cliff and Cowleds Landing. Species identification could not be made with certainty but these specimens appeared to be most similar to *Laurencia shepherdii* Saito & Womersley (1974).

Genus **Lophosiphonia** Falkenberg in Schmitz & Falkenberg 1897

L. subadunca (Kuetzing) Falkenberg 1901: 496, pl.9, figs. 21-24. Cribb 1956: 139. May 1965: 380. Taylor 1960: 605.
Type Locality: Corsica.
Reported Distribution: Arabia; southern Australia; Bahamas; Mediterranean; Queensland; Texas.
Specimen Examined: LTB 12376.
Remarks: *L. subadunca* was common at Wallaroo in June, but absent in March. Plants were sterile, up to 2 cm tall, and occupied the lower portion of *A. marina* pneumatophores under the canopy. According to Cribb (1956) *L. subadunca* has not been recorded from southern Australia.

Genus **Polysiphonia** Greville 1824

P. infestans Harvey 1855: 539. Womersley 1979: 481, fig. 6A-E.
Type Locality: Princess Royal Harbour, King George Sound, W. Australia.
Reported Distribution: From North Beach Reef, Perth, southwards and along the southern Australia coast. Botany Bay, New South Wales.
Specimens Examined: LTB 12232, 12299.
Remarks: Sterile plants up to 3 cm tall, were encountered on the lower portion of pneumatophores.

P. scopulorum Harvey 1855: 540. Womersley 1979: 467, fig. 2A-E.
Type Locality: Rottnest Island, W. Australia.
Reported Distribution: From Rottnest Island, W. Australia to Lawrence Rock, Victoria.
Specimens Examined: LTB 12205, 12218.

TABLE 3
MORPHOLOGIC AFFINITIES OF THE SPENCER GULF *Cladophorella* WITH OTHER DESCRIBED SPECIES

Species of *Cladophorella*	Cell dia. range (µm)	Cell length: width ratio	Cell wall structure	Cell wall dia. (µm)	Reported habitat and references
C. calcicola	23-39	3-10	Lamellate	8	Hot house walls, Cambridge Botanical Gardens (Fritsch 1944). *A. marina* mangrove environment in Queensland (Cribb 1979). Semi-marine cavern in Queensland (Cribb 1965).
C. fritschii	55-88	1½-3½	Lamellate	3-15	Freshwater environment in East Pakistan (Islam 1964).
C. sundarbanensis	15-55	2½-6	Not Lamellate	2-4	Mangrove environment in Bangladesh (Islam 1973). Brackish water in East Pakistan (Islam 1964).
C. marina	80-240	1-5	Lamellate	Not Supplied	Marine environment, New Zealand (Chapman 1956).
Spencer Gulf *Cladophorella*	140-250	1-4	Lamellate	10-50	*Avicennia marina* mangrove environment in Spencer Gulf.

REMARKS: Sterile plants, 2 cm tall, were epiphytic on *C. onustum* under the canopy, and attached to a single pneumatophore in a tidal creek, at Red Cliff. Cribb (1979) recorded this species from Queensland mangroves.

P. subtilissima Montagne 1840: 199. Womersley 1979: 469, fig. 2F-I.

TYPE LOCALITY: Cayenne, French Guiana.

REPORTED DISTRIBUTION: Tropical and sub-tropical Eastern America, French Guiana, Hawaiian Islands; in southern Australia from Coffin Bay, South Aust., to Port Phillip Bay, Victoria; Tasmania; Botany Bay, New South Wales.

SPECIMEN EXAMINED: LTB 12255.

REMARKS: Tetrasporangial plants, up to 3 cm tall, were attached to continually submerged and mud-flat pneumatophores at Arno Bay.

P. teges Womersley 1979: 494, fig. 10A-C.

TYPE LOCALITY: Frenchmans Bay, Albany, W. Australia.

REPORTED DISTRIBUTION: Type locality and Spencer Gulf, S.A.

SPECIMENS EXAMINED: LTB 12174, 12265, 12284, 12352.

REMARKS: Specimens occurred epiphytically on *Cystophyllum onustum* at Cowleds Landing and on the lower portions of pneumatophores at Wallaroo, Port Augusta, and Blanche Harbour. Tetrasporangial plants were collected at the latter two locations. The only previously known specimens from Spencer Gulf were epilithic (Womersley 1979, H. B. S. Womersley pers. comm.).

FREQUENCY DATA

Frequency data for the 42 species collected from the belt transects are summarized in Table 4. Seven taxa (*Bostrychia radicans*, *Caloglossa leprieurii*, *Cladophorella marina*, *Enteromorpha* sp., *Gelidiella tenuissima*, *Rhizoclonium riparium*, *Rivularia atra*) occurred commonly ($F = 0.50$ to 0.75) or abundantly ($F > 0.75$) at one or several localities, and based on mean frequency values [i.e. $\Sigma F/N$, where ΣF is the sum of all recorded frequencies >0 and N is the total number of localities at which the alga occurred; see Table 4], *Caloglossa leprieurii* is the most conspicuous alga in Spencer Gulf mangrove ecosystems. Although all seven taxa were recorded from a majority of study sites, none

TABLE 4
FREQUENCY DATA FOR ALGAE ASSOCIATED WITH SPENCER GULF MANGROVES.
Taxa found outside sampling transects are recorded as present (P).

Taxon	ARNO BAY	BLANCHE HARBOUR	COWLEDS LANDING	FRANKLIN HARBOUR	PORT AUGUSTA	PORT BROUGHTON	PORT DAVIS	RED CLIFF	TUMBY BAY	WALLAROO	MEAN FREQUENCY (F)
CHLOROPHYTA											
Chaetomorpha aerea	0.11									0.09	0.10
C. capillaris		0.05									0.05
Cladophara sp.	0.17	0.27	0.02	0.20	0.21	P		0.03	0.04	0.26	0.16
Cladophorella marina	0.31	0.02	0.75	0.17	0.06			0.01	0.18	0.48	0.25
Enteromorpha sp.	0.27	0.26	0.02	0.22	0.57	P	0.55		0.30		0.31
Percursaria percursa	0.33	0.30		0.02				0.14	0.15	0.33	0.21
Rhizoclonium implexum	0.06			0.05			0.06		0.34	0.06	0.11
R. riparium	0.52		0.06	0.44	0.37	P	0.84	0.26	0.04	0.13	0.33
Sporocladopsis novaezelandiae			0.05	0.02					0.04		0.06
Ulva lactuca	0.24			0.24	0.02		0.02			0.13	0.13
CYANOPHYTA											
Rivularia atra		0.09	0.54	0.34	0.49			0.20	0.05	0.50	0.31
R. polyotis		0.11	0.26	0.02				0.22			0.15
PHAEOPHYTA											
Cystophyllum onustum			P					P			
Dictyota sp.			P					P		P	
Ectocarpus siliculosus	0.02										0.02
Ectocarpus sp.					0.02						0.02
Giffordia sordida										P	
Hormosira banksii			0.01	0.01						0.09	0.04
Kuetzingiella sp.	0.07	0.02	0.05	0.05	0.03				0.18		0.07
Sphacelaria furcigera	0.09			0.11	0.02			0.01			0.12
S. tribuloides				0.04	0.02			0.01			0.04

was encountered at all nine transect localities. Moreover, all seven taxa also occurred only rarely ($F<0.05$) or sporadically ($F=0.05$ to 0.24) at one or more localities and except at Wallaroo, frequency values for *Gelidiella tenuissima* never exceeded 0.13.

Nine additional taxa (*Bostrychia moritziana*, *Centroceras clavulatum*, *Chondria* sp., *Cladophora* sp., *Kuetzingiella* sp., *Percursaria percursa*, *Rhizoclonium implexum*, *Spyridia filamentosa*, *Ulva lactuca*) also occurred at a majority of study sites, but with relatively few exceptions, these species occurred rarely ($F<0.05$) or sporadically ($F=0.05$ to 0.24) and none was ever common or abundant.

In addition to the above 16 taxa, 4 (*Diplocladia patersonis*, *Gelidiella nigrescens*, *Heterodermia* sp., *Neogoniolithon* sp.) occurred with occasional frequencies ($F=0.25$ to 0.49) at Wallaroo. Overall, however, these algae occurred at only 1-3 study sites and were rare or sporadic except at Wallaroo. The remaining 21 algae were detected only at a minority of study sites, always were rare or sporadic, and thus appear to be of relatively little significance in Spencer Gulf mangrove ecosystems.

At a particular locality, 3 to 12 species occurred with frequencies of 0.25 or more, and except for Blanche Harbour and Tumby Bay, at least one species was common ($F=0.50$ to 0.75) or abundant ($F>0.75$). Four of the 7 species found at Port Davis were common or abundant, while other localities only 1 or 2 common or abundant taxa were present. At all study sites except Port Broughton, either *Caloglossa leprieurii* or *Bostrychia radicans* or both occurred with frequencies of 0.25 or more. Frequency data were not obtained for Port Broughton, but neither *Bostrychia* nor *Caloglossa* plants were found there. At Wallaroo, eight red algae with frequencies of 0.25 or more were present; no more than 3 such red algae occurred at any other site. Similarly 5 green algae with frequencies of 0.25 or more grew at Arno Bay while at all other localities no more than 3 such species occurred. Blue green algae became occasional to abundant ($F\geq0.25$) at Cowleds Landing, Franklin Harbour, Port Augusta, and Wallaroo but brown algae occurred only rarely or sporadically at localities where they were present.

DISCUSSION

The marine algal flora of cool temperate Australia is rich and diverse in species, often with a biomass predominance of larger brown algae (especially Fucales) and a high percentage (71%) of endemic genera (Womersley 1981b). This contrasts with the comparatively depauperate algal flora in Spencer Gulf mangrove ecosystems, mostly consisting of red algae

TABLE 4 (Continued)

Taxon	ARNO BAY	BLANCHE HARBOUR	COWLEDS LANDING	FRANKLIN HARBOUR	PORT AUGUSTA	PORT BROUGHTON	PORT DAVIS	RED CLIFF	TUMBY BAY	WALLAROO	MEAN FREQUENCY (F)
RHODOPHYTA											
Audouinella botryocarpa	0.09										0.09
A. daviesii	0.06										0.06
A. saviana	0.03										0.03
Asterocytis ornata	0.01		0.02			P		0.02	0.01		0.02
Bostrychia maritsiana		0.10	0.16	0.26			0.46	0.20		0.09	0.21
B. radicans	0.44	0.15		0.12			0.50	0.30	0.43	0.36	0.33
Caloglossa leprieurii	0.72	0.25	0.45	0.56	0.60		0.77	0.58		0.08	0.50
Centroceras clavulatum	0.01			0.04				0.06	0.22	0.06	0.08
Chondria sp.	0.12			0.01				0.03	0.04	0.03	0.05
Diplocladia patersonis				0.01					0.02	0.28	0.10
Erythrotrichia carnea	0.18										0.18
Gelidiella nigrescens										0.32	0.32
G. tenuissima	0.13		0.07		0.01			0.03		0.51	0.15
Gelidium pusillum										P	
Herposiphonia sp. "A"			0.05							0.07	0.06
Herposiphonia sp. "B"										0.07	0.10
Heteroderma sp.			0.07							0.32	0.17
Jania sp.										P	
Laurencia sp.								0.04		0.08	0.06
Lithothamnium sp.				0.12							0.12
Lophosiphonia subadunca										P	
Neogoniolithon sp.			0.16							0.30	0.23
Phymatolithon sp.										0.03	0.03
Polysiphonia infestans				0.02					0.04		0.03
P. scopulorum								P			
P. subtilissima	0.05										0.05
P. tegea		0.04	P		0.03					0.24	0.10
Spyridia filamentosa	0.09	0.02	0.01	0.06		P		0.17	0.23	0.25	0.12

which have wide distributions. Based on published species estimates (Womersley 1981b: 301) only 10 (9.8%) of the 97 Chlorophyta, nine (4.4%) of the 203 Phaeophyta and 28 (3.5%) of the 800 Rhodophyta species known to occur in southern Australia seas were encountered in Spencer Gulf mangrove ecosystems. Only one alga (*Diplocladia patersonis*), of the 49 reported is endemic to southern Australia; the remaining 48 taxa are more widespread and nearly all have been reported outside Australian waters. All species recorded in Spencer Gulf are known to occur on open coastlines.

Four species (*Cladophorella marina*, *Gelidiella nigrescens*, *Gelidiella tenuissima*, *Lophosiphonia subadunca*) found during this study, are generally considered tropical, and have not been reported previously from the southern coast of Australia.

The genus *Cladophorella* has not been reported from southern Australia (see Womersley 1956, 1971) and the only record of *Gelidiella* from the southern region of Australia is *G. ramellosa* which was originally described as *Acrocarpus ramellosus* by Sonder (1848) from an unspecified locality in Western Australia (see also Kuetzing 1868, Tab. 34 d-f). Three other tropical algae (*Acetabularia calyculus*, *Hormophysa triquetra*, *Sargassum decurrens*) have been recorded outside the mangrove environment in Spencer Gulf (Womersley 1981b).

Numerous hypotheses have been proposed to explain disjunct distributions of marine benthic algae. These include:

1. Spread by shipping (Farnham *et al.* 1973, Lewis & Kraft 1979, Womersley 1981b);
2. Ocean currents (Womersley, 1981b);
3. Continental drift (Chapman 1953); and
4. The possibility that they are relict populations (Womersley 1981b).

The establishment of algal species distant from their modern recorded natural distributions was tentatively attributed to transport on shipping for *Schottera nicaeensis* (Lamouroux ex Duby) Guiry and Hollenberg in Port Phillip Bay (Lewis & Kraft 1979) and for *Sargassum muticum* and other algae in Britain (Farnham 1980, Farnham *et al.* 1973). This hypothesis is based on the apparent absence of these species from previous floristic records and their recent appearance near busy shipping ports. Spread by ocean currents over

long distances seems to be of rare occurrence, due to the short life of algal spores and drifting fragments (Womersley 1981b).

An alternative hypothesis is that the isolated populations in Spencer Gulf are relics of warmer climatic periods when their natural distributions may have been quite different, and that they are able to survive in Spencer Gulf because the summer water temperatures are sufficiently high for reproduction to occur (Womersley 1981b). These populations may be relict from the Cretaceous era (70-130 million years ago) when an inland sea (Brown *et al.* 1968) joined southern Australia to the tropical waters of the Arafura sea.

Continental drift has been another hypothesis used to explain the disjunct distribution of algae (Chapman 1953). Chapman (1953) used an example of three genera (*Ecklonia*, *Macrocystis*, *Splachnidium*) which occur in both South Africa and South America. This hypothesis fails to explain the occurrence of tropical species in Spencer Gulf because, prior to continental drift (Coulomb 1969), southern Australia was connected to the Antarctic.

On the available data, it seems equally possible, that the species with tropical affinities are remnants of an earlier climatic period or, since Spencer Gulf includes a number of ports, that the algae may also have been transported by shipping. The least likely hypothesis to explain the occurrence of tropical algae in Spencer Gulf is continental drift.

Of the 10 localities examined, Blanche Harbour, Port Augusta and Red Cliff were subject to the higher salinities and surface water temperatures of the far north of Spencer Gulf while the remaining seven sites were situated in areas of more moderate salinity and temperature further south. The total flora in the far northern region (30 taxa) was less diverse than in more southern sites (47 taxa), and only one taxon (*Ectocarpus* sp.) appeared to be confined to the far north. Hence, high salinity or surface water temperature may restrict mangrove algal community composition. Davey and Woelkerling (1980) also found that the estuarine (brackish water) influence adversely affects algal diversity on Victorian mangroves. Species of *Bostrychia* and *Caloglossa*, however, occur in the estuarine environment in Victoria, the high salinity region of northern Spencer Gulf, and are widespread in tropical Queensland (Cribb 1979) and outside of Australian waters (Post 1963). Their widespread distributions may be attributed to their high resistance to osmotic shock, desiccation or temperature extremes and/or salinity extremes (e.g. Biebl 1962, Davis & Dawes 1981, Yarish *et al.* 1979, Yarish *et al.* 1981). Further studies would be required to determine whether the more characteristic mangrove algae have a relatively higher tolerance to stressed conditions than other species with more limited distributions.

The total number of species (Chlorophyta, Phaeophyta, Rhodophyta) in Spencer Gulf mangrove algal communities is far more diverse than heretofore realised; 43 (88%) of the species found during this study were not recorded previously from South Australian mangrove ecosystems. The total number of mangrove algae in Spencer Gulf (Table 5) is comparable to that reported (Cribb 1979, Saenger *et al.* 1977) from *Avicennia* pneumatophores in tropical Queensland (47 taxa), but more diverse than reported (Davey & Woelkerling 1980) from Victorian mangroves (23 taxa). It was thought previously (Davey & Woelkerling 1980) that the species richness of temperate Victorian mangrove communities was comparable to that reported by Saenger *et al.* (1977) from tropical Queensland (23 taxa). The recent floristic contribution of Cribb (1979), however, has indicated that the Queensland communities are more species rich (Table 5).

Species composition differs substantially between these three regions of Australia. Of the 10 recorded species of Chlorophyta in Spencer Gulf, two occurred in Queensland and three in Victoria; of the 28 recorded Rhodophyta, six occurred in Queensland and four in Victoria; of the nine Phaeophyta, none have been reported in Queensland or in Victoria. Thus, only 20% of the total eucaryotic macroscopic algal flora in Spencer Gulf has been reported from Queensland and only 17% from Victoria. *Percursaria percursa* and *Diplocladia patersonis* are common to Spencer Gulf and Victorian mangrove communities and do not occur on tropical Queensland mangroves. Because no distinction has been made in most cases between those taxa present in mangrove ecosystems and those taxa present in salt marsh ecosystems in New South Wales (King 1981a: 323-324, Saenger *et al.* 1977), only a few algal taxa (Table 5) are recorded unequivocally from New South Wales mangroves and meaningful comparisons with the Spencer Gulf flora are not possible. Absence of detailed data prevents biogeographic comparisons of the Spencer Gulf algal flora with those of Northern Territory, Western Australia, and other parts of South Australia (Gulf St. Vincent, Streaky Bay—Ceduna region).

Bostrychia and *Caloglossa* were thought not to occur on South Australian mangroves (Womersley 1981a), but this study has revealed that they are two of the most widespread and common algae in Spencer Gulf communities. All species of these two genera, also have been found on mangroves in Queensland and Victoria. Eight additional species of *Bostrychia* and two additional species of *Caloglossa* occur on Queensland mangroves, and two additional species of *Bostrychia* occur on Victorian mangroves. Species of *Catenella*, widespread in other mangrove ecosystems, were not found in Spencer Gulf.

Frequency data from Spencer Gulf (Table 4) and Victoria (Davey & Woelkerling 1980) suggest that the mangrove algal communities of the two regions are similar in some respects but differ in others. In both regions, *Caloglossa leprieurii* is the most conspicuous taxon. *Bostrychia radicans* was occasional, common, or abundant at many localities in both areas, while species of *Enteromorpha* and *Ulva* appear to occur with a similar range of frequencies in Spencer Gulf and Victoria.

TABLE 5
BIOGEOGRAPHIC COMPARISONS OF THE ALGAL FLORA RECORDED FROM MANGROVE ECOSYSTEMS IN SOUTH AUSTRALIA, NEW SOUTH WALES, QUEENSLAND AND VICTORIA, WITH THOSE OF SPENCER GULF (Reference sources are numerically coded)

	Spencer Gulf, S.A. (Present Study)	South Australia (1,7,8,9)	N.S.W. (4,5,6)	QLD. (2,6)	VIC. (3)	Reported Australian Mangrove Algae (Present Study +1–9)
Chlorophyta	10	3	–	14	6	22
Chrysophyta	–	–	–	–	1	1
Phaeophyta	9	1	1	3	3	13
Rhodophyta	28	–	6	30	13	53
Total	47	4	7	47	23	89
Bostrychia	3	–	3	10	4	12
Caloglossa	1	–	1	3	1	3
Catenella	–	–	1	2	1	2
Total	4	–	5	15	6	17

References
1, Butler *et al.* (1977b); 2, Cribb (1979); 3, Davey & Woelkerling (1980); 4, King (1981a); 5, King (1981b); 6, Saenger (1977); 7, Specht (1972); 8, Womersley & Edmonds (1958); 9, Wood (1937).

In contrast, *Cladophorella marina* and *Rivularia atra*, fairly conspicuous components of Spencer Gulf mangrove ecosystems, were not found in Victoria, and conversely *Bostrychia intricata* and *Catenella nipae* were widespread and often prevalent in Victoria but were not found in Spencer Gulf mangroves. *Hormosira banksii*, not recorded by Davey & Woelkerling (1980) from Victorian mangroves, occurs only rarely or sporadically in Spencer Gulf mangroves studied. This contrasts with the reports of Butler *et al.* (1977a, 1977b) who regard *H. banksii* as common in South Australian mangroves and with the record of Clarke and Womersley (1981: 500) from St. Vincent Gulf.

In Victoria, 3-5 prevalent ($F \geq 0.50$) species occurred at half of the 16 study sites and at least 1 prevalent species was present at every locality. In Spencer Gulf, however, only one site (Port Davis, 4 prevalent species) harboured more than 2 prevalent species and at two localities (Blanche Harbour, Tumby Bay) no prevalent species occurred at all. Reasons for the generally lower number of prevalent species at Spencer Gulf study sites remain unclear, and whether a reduction in the number of prevalent species occurs as the overall diversity increases is also uncertain.

Both in Spencer Gulf and in Victoria, a majority of algal taxa found in mangrove ecosystems always appear to be rare ($F < 0.05$) or sporadic ($F = 0.05$ to 0.24). In Victoria, only 10 of the 23 (43%) taxa found registered frequencies greater than 0.24. In Spencer Gulf 16 of 41 (39%) similar taxa occurred. Thus in both regions, only a minority of mangrove algae appear to be potentially well adapted to the environmental stresses present.

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